

UNITED STATES PATENT APPLICATION

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MULTI-DOMAIN LIQUID CRYSTAL DISPLAY DEVICE

This application claims the benefit of Korean Patent Application No. P 1999-67766, filed on December 31, 1999, which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to relates to a liquid crystal display device, and more particularly, to a multi-domain liquid crystal display device in which a common auxiliary electrode is formed around and/or within a pixel region on a layer equal to a gate line, and a dielectric structure for distorting electric field, an additional dielectric structure or an electric field window are formed within the pixel region together with the common auxiliary electrode.

Discussion of the Related Art

Recently, a liquid crystal display device which drives a liquid crystal by an auxiliary electrode electrically insulated from a pixel electrode without aligning the liquid crystal has been suggested. Such a related art liquid crystal display device will be described with reference to Fig. 1.

Fig. 1 is a sectional view of a unit pixel of the related art liquid crystal display device.

As shown in Fig. 1, the related art liquid crystal display device includes a first substrate, a second substrate, a plurality of data lines and gate lines, a thin film transistor, a passivation film 37, a pixel electrode 13, and an auxiliary electrode 21. The data lines and gate lines are formed on the first substrate lengthwise and crosswise to divide the first substrate into a plurality of pixel

regions. The thin film transistor is formed in each pixel region on the first substrate and includes a gate electrode, a gate insulating film, a semiconductor layer, an ohmic contact layer, and source/drain electrodes. The passivation film 37 is formed on the whole first substrate. The pixel electrode 13 is formed on passivation film 37 to be connected with the drain electrode. The auxiliary electrode 21 is formed on the gate insulating film to partially overlap the pixel electrode 13.

The related art liquid crystal display device further includes a light-shielding layer 25, a color filter layer 23 formed on the light-shielding layer 25, a common electrode 17 formed on the color filter layer 23, and a liquid crystal layer formed between the first substrate and the second substrate. The light-shielding layer is formed on the second substrate to shield light leaked from the gate lines, the data lines, and the thin film transistor.

An open region 27 may be formed in the common electrode 17 to distort electric field applied to the liquid crystal layer. The auxiliary electrode 21 formed around the pixel electrode 13 and the open region 27 of the common electrode 17 distort electric field applied to the liquid crystal layer so that liquid crystal molecules are variously driven within a unit pixel. This is intended that a dielectric energy by the distorted electric field places a liquid crystal director at a desired position when a voltage is applied to the liquid crystal display device.

However, the liquid crystal display device requires the open region 27 in the common electrode 17 to obtain multi-domain effect. To this end, a process for patterning the common electrode is additionally required.

Furthermore, if the open region 27 is not formed or has a small width, distortion range of the electric field required to divide the domain is weak. Accordingly, there is a problem that the time when the liquid crystal director reaches a stable state relatively becomes longer. Moreover, the electric field strongly occurs between the pixel electrode 13 and the auxiliary electrode 21. This increases luminance in only a portion, and also increases response time.

SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to a multi-domain liquid crystal display device that substantially obviates one or more of the problems due to limitations and disadvantages of the related art.

An object of the present invention is to provide a multi-domain liquid crystal display device in which a common auxiliary electrode is formed around and/or within a pixel region on a layer equal to a gate line, and a dielectric structure for distorting electric field, an additional dielectric structure or an electric field window are formed within the pixel region together with the common auxiliary electrode.

Another object of the present invention is to provide a multi-domain liquid crystal display device which reduces response time of a liquid crystal layer and improves luminance.

Other object of the present invention is to provide a multi-domain liquid crystal display device which improves a viewing angle.

Additional features and advantages of the invention will be set forth in the description

which follows, and in part will be apparent from the description, or may be learned by practice of the invention. The objectives and other advantages of the invention will be realized and attained by the scheme particularly pointed out in the written description and claims hereof as well as the appended drawings.

A multi-domain liquid crystal display device of the present invention is an improved invention of the Korean Patent Application No. 1999-05587 filed by the same applicant of this invention, in which a common auxiliary electrode is formed around a pixel region on a layer equal to a gate line, and electric field induction windows are formed in the pixel region in a plurality of particular directions.

To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described, a multi-domain liquid crystal display device according to the present invention includes: first and second substrates; a plurality of gate lines on the first substrate in a first direction; a plurality of data lines formed in a second direction to cross the first direction; a plurality of thin film transistors formed in a portion where the gate lines cross the data lines; a plurality of pixel regions between neighboring gate and data lines; a common auxiliary electrode around each pixel region; a plurality of pixel electrodes formed in each pixel region to connect with the thin film transistor; dielectric structures on the second substrate, the dielectric structures being electric field with the common auxiliary electrode and being divided the pixel region into at least four domains; at least one or more additional structures at an end portion of the dielectric structures within the pixel region; an alignment film on at least one of the first substrate and the second substrate; and a liquid crystal layer between

the first substrate and the second substrate.

The multi-domain liquid crystal display device further includes at least one or more electric field induction windows within the pixel region to compensate the dielectric structures. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWING

The invention will be described in detail with reference to the following drawings in which like reference numerals refer to like elements wherein:

Fig. 1 is a sectional view showing a related art liquid crystal display device;

Fig. 2 is a plane view showing a multi-domain liquid crystal display device according to the first embodiment of the present invention;

Fig. 3 is a plane view showing a multi-domain liquid crystal display device according to the second embodiment of the present invention;

Fig. 4 is a plane view showing a multi-domain liquid crystal display device according to the third embodiment of the present invention;

Figs. 5a and 5b are a plane view showing a multi-domain liquid crystal display device according to the fourth embodiment of the present invention; and

Figs. 6a to 6e are sectional views taken along line I-I' of Fig. 2, showing a method for fabricating a multi-domain liquid crystal display device according to the present invention.

Fig. 7 is a plane view showing a multi-domain liquid crystal display device applying to phase difference film.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

Fig. 2 is a plane view showing a multi-domain liquid crystal display device according to the first embodiment of the present invention.

A multi-domain liquid crystal display device of the present invention includes a first substrate 31, a second substrate 33, a plurality of data lines 3 and gate lines 1, a common auxiliary electrode 15, a thin film transistor, a passivation film 37, and a pixel electrode 13.

The data lines 3 and gate lines 1 are formed on the first substrate 31 lengthwise and crosswise to divide the first substrate into a plurality of pixel regions. The common auxiliary electrode 15 is formed around and/or within the pixel regions on a layer equal to the gate lines. The thin film transistor is formed in each pixel region on the first substrate and includes a gate electrode 11, a gate insulating film 35, a semiconductor layer 5, an ohmic contact layer 6, and source/drain electrodes 7 and 9. The passivation film 37 is formed on an entire surface of the first substrate 31. The pixel electrode 13 is formed on the passivation film 37 to be connected with the drain electrode 9.

The multi-domain liquid crystal display device further includes at least one or more electric field induction windows 51 in a corner portion within the pixel electrode 13 to

compensate the electric field applied and induced to the common auxiliary electrode 15 and the pixel electrode 13 (see Fig. 3).

The electric field induction windows 51 acts to decrease disclination portion, so the brightness and the response time can be improved.

The multi-domain liquid crystal display device further includes a light-shielding layer 25, a color filter layer 23 formed on the light-shielding layer 25, a common electrode 17 formed on the color filter layer 25, and a liquid crystal layer formed between the first substrate 31 and the second substrate 33. The light-shielding layer 25 is formed on the second substrate 33 to shield light leaked from the gate lines 1, the data lines 3 and the thin film transistor.

Dielectric structures 53 of double Y shapes with curve portions are formed on the common electrode 17 and acts to remove disclination generated due to uneven electric field applied to the related art common electrode and pixel electrode (see Fig. 2). Also, in addition to the dielectric structures, at least one or more additional dielectric structures may be formed on the common electrode 17 to compensate the electric field induced to the corner portion of the pixel region.

The dielectric structures include a first region formed in one direction within the pixel region, and second and third regions respectively divided from an end portion of the first region (see Fig. 4).

The end portion of the dielectric structures 53 acts to remove disclination due to uneven electric field, so the flicker is prevented and the brightness is increased.

In the fourth embodiment of the present invention shown in Fig. 5, one pixel is divided

into three parts, and the common auxiliary electrode 15 is formed within each part in a hexagonal shape. At the same time, the dielectric structures 53 are formed in a portion, where the common auxiliary electrode 15 is not formed, on the second substrate. Thus, more improved multi-domain effect can be obtained.

Namely, each part is defined by the dielectric structures 53 formed in a diagonal direction of each corresponding part and the common auxiliary electrode 15 formed in a hexagonal shape around the dielectric structures. The dielectric structures 53 are formed in a zig-zag shape along with a neighboring dielectric structure. So, the zig-zag shape acts to have an uniform electric field distortion, and the aperture ratio and the response time can be improved.

Meanwhile, the common auxiliary electrode 15 has an extension portion to be connected with a neighboring common auxiliary electrode 15. Fig. 5b is a sectional view taken along line II-II' of Fig5a.

In the fourth embodiment, the dielectric structures on the second substrate may have hole or slit shapes to act as the electric field windows.

Figs. 6a to 6e are sectional views taken along line I-I' of Fig. 2, showing a method for fabricating a multi-domain liquid crystal display device according to the present invention.

To fabricate the aforementioned multi-domain liquid crystal display device, the thin film transistor consisting of the gate electrode 11, the gate insulating film 35, the semiconductor layer 5, the ohmic contact layer 6 and the source/drain electrodes 7 and 9 is formed in each pixel region of the first substrate 31. At this time, the plurality of gate lines 1 and data lines 3 are formed to divide the first substrate 31 into a plurality of pixel regions.

The gate electrode 11 and the gate lines 1 are formed in such a manner that a metal such as Al, Mo, Cr, Ta, Al alloy, or their double layer is layered by sputtering method and patterned. At the same time, the common auxiliary electrode 15 is formed in one pixel to have at least one or more electrodes, and conducted to the common auxiliary electrode of a neighboring pixel (Fig. 6a).

When the common auxiliary electrode 15 is formed of the same material as that of the gate lines 1, the common auxiliary electrode 15 is formed on the same layer as the gate lines 1 using the same mask and electrically connected with the common electrode 17. Alternatively, the common auxiliary electrode 15 may be formed of a metal different from the material of the gate lines using an additional mask. Also, the common auxiliary electrode 15 may be formed of a double layer with different materials.

Subsequently, the gate insulating film 35 is formed in such a manner that SiN_x or SiO_x is deposited on the common auxiliary electrode 15 and the gate lines 1 by plasma enhancement chemical vapor deposition (PECVD) method. To improve aperture ratio, benzocyclobutene(BCB), acrylic resin, or polyimide(PI) compound may be used as the gate insulating film 35.

Subsequently, the semiconductor layer 5 and the ohmic contact layer 6 are formed in such a manner that a-Si and n^+ a-Si are deposited by the PECVD method and patterned (Fig. 6b). Alternatively, the semiconductor layer 5 and the ohmic contact layer 6 are formed in such a manner that a-Si and n^+ a-Si are patterned after SiN_x or SiO_x , a-Si and n^+ a-Si are successively deposited to form the gate insulating film 35.

A metal such as Al, Mo, Cr, Ta, Al alloy, or their double layer is layered by the sputtering method and then patterned so that the data lines 3 and the source/drain electrodes 7 and 9 are formed (Fig. 6c). At this time, a storage electrode 43 is formed to overlap the gate lines 1 and/or the common auxiliary electrode 15. The storage electrode 43 acts as a storage capacitor together with the gate lines 1 and/or the common auxiliary electrode 15.

Subsequently, the passivation film 37 is formed of a material such as BCB, acrylic resin, polyimide compound, SiN_x or SiO_x on the whole first substrate 31. An indium tin oxide(ITO) is deposited by the sputtering method and patterned to form the pixel electrode 13 (Fig. 6d).

Fig. 6 shows a case where the passivation film 37 is SiN_x or SiO_x . In case where BCB, acrylic resin or polyimide compound is used as the passivation film 37, planation of the surface can be obtained and at the same time aperture ratio can be improved.

The storage electrode 43 is extended toward the pixel electrode 13 to partially overlap the pixel electrode 13, and a contact hole 39 is formed by removing the passivation film beneath the overlap portion. Thus, the pixel electrode 13 is electrically connected with the storage electrode 43. Furthermore, the passivation film on the drain electrode 9 is selectively removed to form the contact hole 39 so that the pixel electrode 13 is connected with the drain electrode 9 through the contact hole 39 (Fig. 6e).

At the same time, at least one or more additional electric field induction windows 51 are formed in the corner portion within the pixel electrode 13. The electric field induction window acts to compensate the electric field formed by the common auxiliary electrode 15 so that a stable liquid crystal structure can be obtained when driving the liquid crystal display device. Thus,

response time of the liquid crystal display device can be reduced.

Additionally, an alignment film (not shown) may be formed on the pixel electrode 13.

In the embodiments of the multi-domain liquid crystal display device according to the present invention, L-lined thin film transistor structure of high aperture ratio is provided. By forming the L-lined thin film transistor on the gate lines 1, aperture ratio can be improved as compared with the related art liquid crystal display device and parasitic capacitance generated between the gate line 1 and the drain electrode 9 can be reduced.

The light-shielding layer 25 is formed on the second substrate 33, and the color filter layer 23 is formed to repeat R(red), G(green) and B(blue) elements for each pixel. The common electrode 17 is formed of a transparent electrode such as ITO on the color filter layer 23, in the same manner as the pixel electrode 13. A photoresist material is deposited on the common electrode 17 and patterned by photolithography to form dielectric structures 53 having various shapes. Additionally, an alignment film (not shown) may be formed on the dielectric structures 53.

Subsequently, a liquid crystal is injected between the first substrate 31 and the second substrate 33 so that a multi-domain liquid crystal display device is completed. The liquid crystal constituting the liquid crystal layer has a positive dielectric anisotropy or a negative dielectric anisotropy. The liquid crystal may include a chiral dopant.

Preferably, the dielectric structures 53 have dielectric constants equal to or smaller than the liquid crystal layer, and more preferably 3 or below. A material such as photoacrylate or BCB may be used as the dielectric structures.

To apply a voltage V_{com} to the common auxiliary electrode 15, an Ag-Dotting portion is formed in each corner of a driving region of the liquid crystal display device on the first substrate 31, and the electric field is applied to the second substrate 33 to drive the liquid crystal by the potential difference between upper and lower substrates. The Ag-Dotting portion of each corner is connected with the common auxiliary electrode 15. Thus, the voltage V_{com} is applied to the common auxiliary electrode 15. This process is performed when forming the common auxiliary electrode 15.

High molecules are formed on at least one of the first substrate 31 and the second substrate 33 so that a phase difference film 29 is formed.(as shown in Fig 7.)

The phase difference film 29 is a negative uniaxial film and acts to compensate a viewing angle of a user. Therefore, a region having no gray inversion is expanded, contrast ratio in tilt direction increases, and a multi-domain is formed by one pixel. Thus, a viewing angle in left and right direction can effectively be compensated.

In addition to the negative uniaxial film, a negative biaxial film may be formed as the phase difference film 29. The negative biaxial film having two axes can obtain viewing angle characteristic wider than the negative uniaxial film.

Subsequently, a polarizer(not shown) is attached on both substrates. The polarizer may be formed in an integral form with the phase difference film.

In the multi-domain liquid crystal display device of the present invention, the dielectric structures 53 are formed on the pixel electrode and/or the common electrode, or the pixel electrode, the passivation film, the gate insulating film, the color filter layer, the overcoat layer, and/or the common electrode are patterned to form the electric field induction windows 51 such as a hole or slit therein. Thus, electric field distortion effect and multi-domain effect can be

obtained.

Four-domain or multi-domain effect can be obtained by the electric field induction windows 51 or the dielectric structures 53. The electric field induction windows 51 or the dielectric structures 53 may be formed on at least one of the first substrate and the second substrate, or independently or together on both substrates.

Additionally, in the multi-domain liquid crystal display device of the present invention, an alignment film (not shown) is formed over the first substrate and/or the second substrate.

Polyamide or polyimide based compound, polyvinylalcohol(PVA), polyamic acid, or SiO₂ is used as an alignment material of the alignment film. In case where rubbing method is used to determine alignment direction, a material suitable for the rubbing method may be used as the alignment material of the alignment film.

Furthermore, a photo alignment film of a material such as polyvinylcinnamate(PVCN), polysiloxanecinnamate(PSCN), cellulosecinnamate(CelCN), or their based compound may be formed. The other materials suitable for photo-alignment may be used as the alignment film.

Light is irradiated to the photo-alignment film at least one time to determine a pretilt angle and alignment direction or pretilt direction of the director of the liquid crystal molecule at the same time, thereby obtaining stable alignment of the liquid crystal. The light used for the photo-alignment is suitable for light in an ultraviolet ray region. Non-polarized light, linearly-polarized light, unpolarized light, or partially polarized light may be used for the photo-alignment.

The rubbing method or the photo-alignment method is applicable to one of the first substrate and the second substrate or both substrates. Different alignment methods are applicable to both substrates. Although the alignment film has been formed, alignment process may not be

performed.

Furthermore, the aforementioned alignment is performed to form the multi-domain liquid crystal display device divided into at least two regions. Thus, the liquid crystal molecule of the liquid crystal layer may be aligned differently on each region. In other words, each pixel is divided into four regions in + shape or X shape, or each pixel is divided in horizontal, vertical, or diagonal direction. Alignment process or alignment direction is varied depending on each region and each substrate, so that multi-domain effect can be realized. At least one region of the divided regions may be a non-alignment region or all the divided regions may be a non-alignment region.

As aforementioned, the multi-domain liquid crystal display device has the following advantages.

The common auxiliary electrode is formed around and/or within the pixel region on the same layer as the gate lines, and the dielectric structures for distorting the electric field together with the common auxiliary electrode and additional dielectric structures or the electric field induction windows for compensating the dielectric structures are formed within the pixel region. Thus, response time of the liquid crystal layer can be reduced and luminance can be improved, thereby maximizing the multi-domain effect.

Also, gray inversion and disclination generated in the related art liquid crystal display device can be removed. Particularly, the viewing angle can effectively be ensured in left and right direction.

The foregoing embodiments are merely exemplary and are not to be construed as limiting the present invention. The present teachings can be readily applied to other types of apparatuses. The description of the present invention is intended to be illustrative, and not

1871 1872 1873 1874 1875 1876 1877 1878 1879 1880 1881 1882 1883 1884 1885 1886 1887 1888 1889 1890 1891 1892 1893 1894 1895 1896 1897 1898 1899 1900 1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2